

Conduction Mechanism of PZT: Silicone Resin Composites In 0-3 Connectivity

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ABSTRACT

In this paper, an attempt has been made to study conduction mechanism of PZT-silicone resin composites in 0-3 connectivity. For this, PZT is prepared by solid state reaction method. The conduction mechanism was determined by analyzing the activation energies. The results have been plotted in graphs. A close examination of the plots revealed that at higher temperatures the slope tends to be mildly steeper compared to the low temperature ones but we had followed a least square fit with respect to a single line and then the activation energies ranging from 0.8 eV to 1.21 eV were determined.

Keywords: PZT, Silicone Resin, Activation energy, Solid state reaction method.

INTRODUCTION

The use of ceramics in electronic components is growing rapidly as a result of their superior physical properties and new technology development. The markets and material technologies for ceramics used as insulators, substrates and packages, capacitors, resistors, semiconductors, piezoelectric devices, and superconductors

have shown an outstanding growth during the last two decades¹. Electronic ceramics provide basic components and also as a support of a variety of electronic products including computers, industrial controllers, consumer automotive devices and digital switches. The most widely used piezoelectric ceramics are lead-based ceramics, especially $\text{Pb}(\text{Zr,Ti})\text{O}_3$ (PZT), because of their superior piezoelectric

properties². In piezoelectric composite materials, the high piezoelectric and dielectric properties of lead zirconium titanate (PZT) ceramics combined with the low density and the high flexibility of polymers make them suitable for different applications³. Piezoelectric composite materials are especially useful for underwater sonar and medical diagnostic ultrasonic transducer applications. In this paper an attempt has been made to study conduction mechanism of PZT ceramic and silicone resin polymer composites in 0-3 connectivity.

EXPERIMENTAL

The starting materials used for the preparation of the composite samples were silicone resin and PZT powder. PZT was prepared by the conventional oxide route i.e., mixing the various oxides viz: PbO, ZrO₂ and TiO₂ in stoichiometric proportions and 5% by gram mol weight of PbO was

replaced by La₂O₃ and ball milled in ethyl alcohol using a rubber lined jar and ZrO₂ balls for 24h. The milled powders were dried, ground, sieved and then calcined at 800 °C for 24h in air. Calcined powders were ball-milled again for 24h and sintered at 1200 °C giving rise to sintered powder of lanthanum doped PZT. The samples were prepared by mixing sintered PZT powder of fine particle size (1-3 μm) in silicone resin. The samples thus formed were composite of PZT and silicone resin in 0-3 connectivity. The conductivity of the sample was studied at different temperatures. To find the activation energies and the mechanism of conductivity in the sample, the conductivities are plotted against the reciprocal of the logarithm of the temperature in absolute scale as depicted in figure (1). The energies (E_a) can be calculated with the help of the relation $\sigma = \sigma_0 \exp(-E_a/kT)$, which implies $\ln \sigma = \ln \sigma_0 - E_a/kT$, therefore a linear relation exists between $\ln \sigma$ and $1/T$ whose slope is $-E_a$.

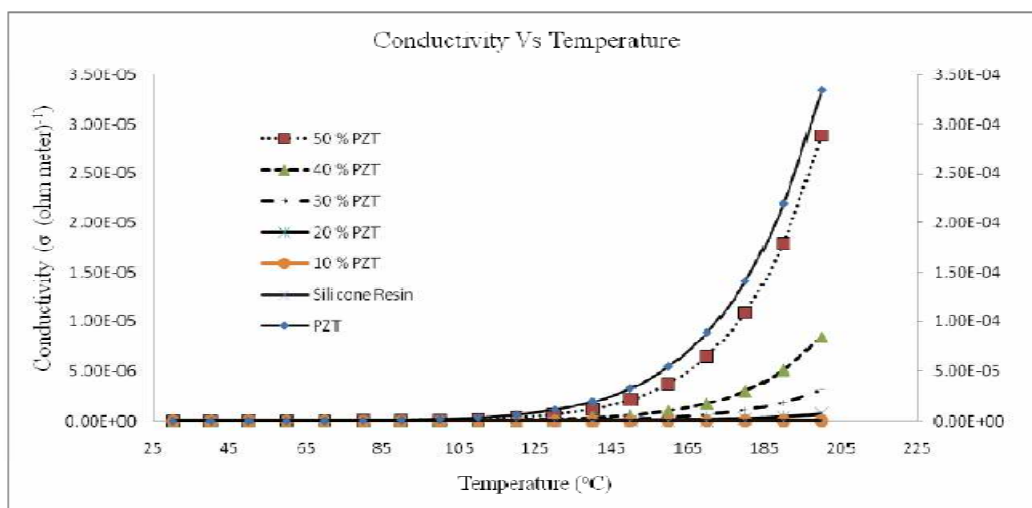


Fig (1): Conductivities of the composite samples as a function of temperature

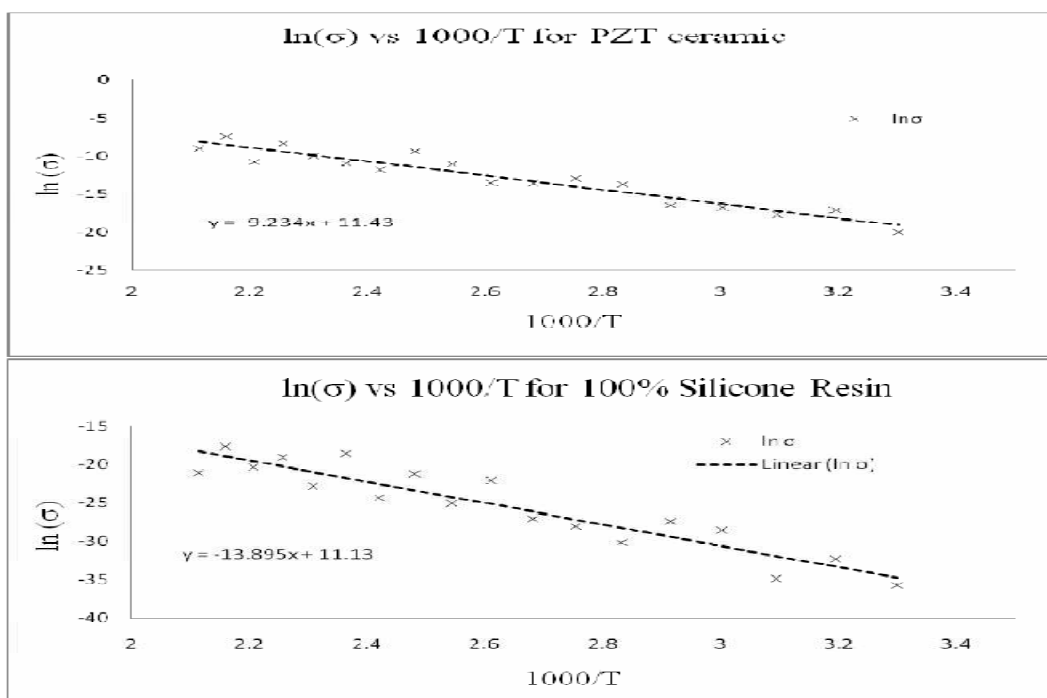


Fig (2): Arrhenius plots of PZT ceramic and silicone resin polymer

Table (1): Activation Energies of the composites

Parameter	Units	PZT	PZT 50%	PZT 40%	PZT 30%	PZT 20%	PZT 10%	Silicone Resin
E_a	eV	0.8	0.9	0.95	0.99	1.05	1.15	1.21

RESULTS AND DISCUSSION

The conductivity studies were carried out and the results are plotted. The activation energies are calculated from the respective graphs. The conduction mechanism was determined by analyzing the activation energies. The conductivities in a ceramic / composites are activated by different charge carriers. The Arrhenius

plots [$\ln$ (conductivity) vs (inverse temperature)] gives a sum total of all the activation energies at high temperatures as shown in figure (2) and (3). At low temperatures the higher activation energies are suppressed and therefore the slopes of the plot at low temperatures are the most important in segregating the different effects due to different species of charge carriers. A close examination of the plots reveals that at

higher temperatures the slope tends to be mildly steeper compared to the low temperature ones but we had followed a least square fit with respect to a single line and then the activation energy was determined. The plots are as shown above.

It can be seen from the figure (4) that a polynomial fit to the observed data on the activation energies of the composites, shows a very high correlation between PZT

% in the composite and the activation energies achieved. From the regressed equation it can be seen that the numerical values of the coefficients of the zeroth and first powers in the equation is much higher than the second and third powers of the polynomial, this implies that one may also consider a linear relationship for most of the practical purpose i.e., more of PZT in the ceramic brings down the activation energies.

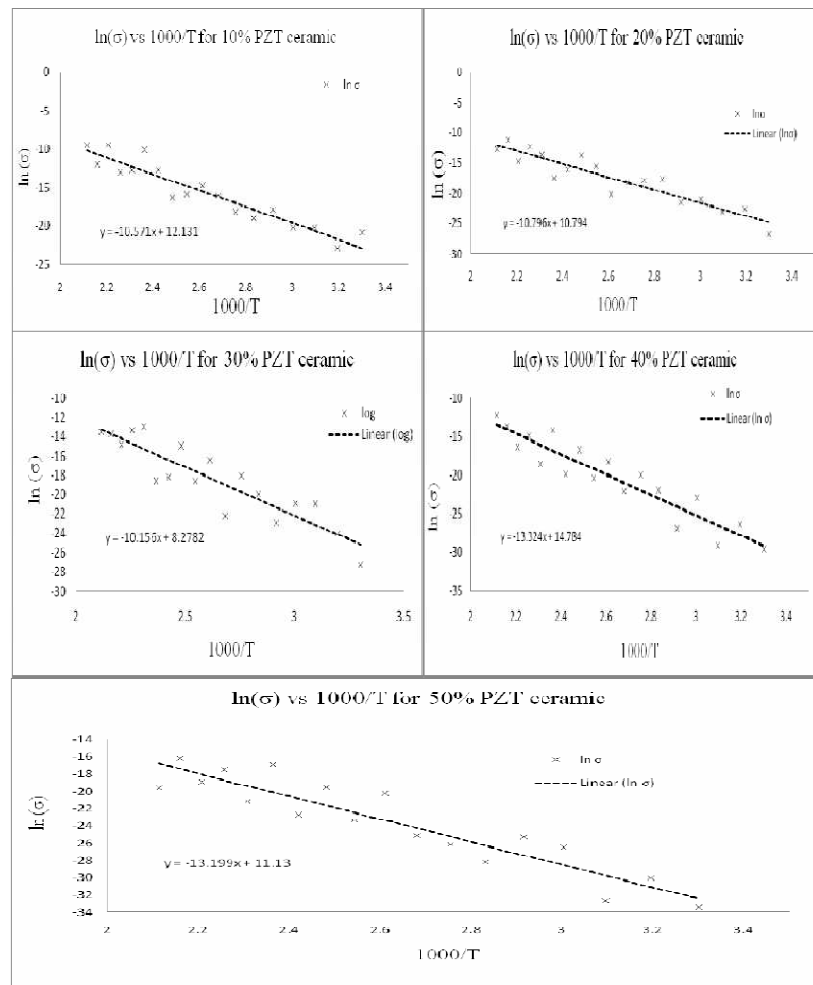


Fig (3): Arrhenius plots for different percentage of PZT and silicone resin composite

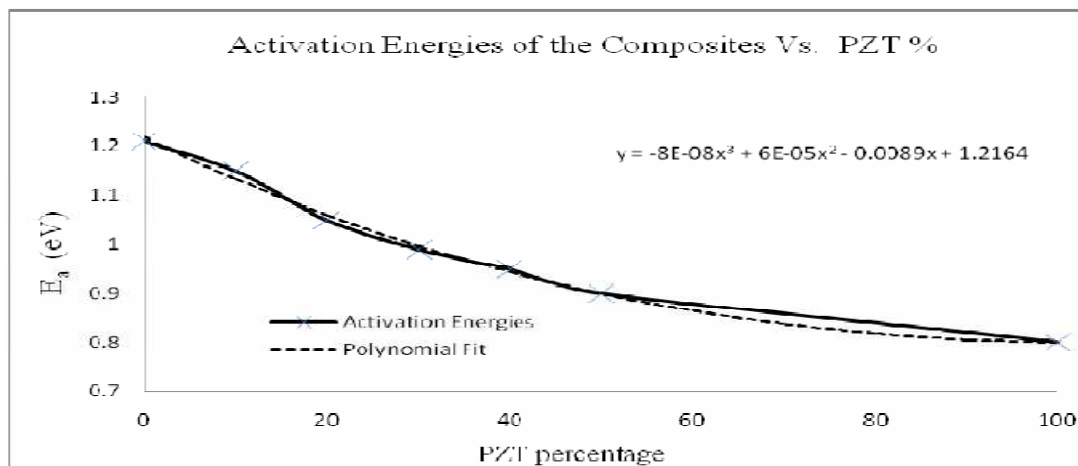


Fig (4): Activation energies of PZT: silicone resin composites as a function of % of PZT

CONCLUSIONS

The conductivity of the samples is typical of a material whose electrical behaviour is like an insulator with some semiconducting properties. The activation energies are typical of charge carriers with mobilities resembling ions and oxygen vacancies, by pinning them or it inhibits the generation of oxygen vacancies. The activation energies calculated from the Arrhenius plots are mentioned in figure (3) and table (1), where E_a the activation energies ranging from 0.8eV to 1.21eV, are characteristic of ionic conductivity along with mobilities of oxygen vacancies in the bulk.

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